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Regular Prepreg, Wide Band Prepreg
and Ordinary Wet Wound Pressure
Vessel Strengths Compared
and
The Effects of Proof Testing
on Vessel Strengths

by
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## FOREWORD

This research memorandum has been written under contract Nonr - 3219(01)(x) by direction of the Scientific Officer. The memorandum was prepared under the direction of Dr. John O. Outwater, Principal Investigator under this contract, and summarizes the work to date on the influence of prepreg rovings and proof testing on the strength of laminated pressure vessels, carried out under the technical direction of the U. S. Naval Research Laboratory.

Mr. Joseph A. Kies and Dr. Irvin Wolock of the U. S. Naval Research Laboratory and Messrs. Miner, Oldham and Trono of the University of Vermont were of great help in the undertaking. The authors also wish to acknowledge the valued advice and encouragement of many others who helped in this project.

# Regular Prepreg, Wide Band Prepreg and Ordinary Wet Wound Pressure Vessel Strengths Compared and The Effects of Proof Testing on Vessel Strengths

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ABSTRACT

A series of laminated pressure vessels was wound with regular prepreg, wide band prepreg and with wet roving. The results indicate no significant increase of strength of wide band over ordinary prepreg though the vessels made with wet winding indicated a significant increase in strength in two rolls out of the three used.

The effects of holding the preload pressure at 80% of burst for a minute significantly reduces the strength compared to merely giving the vessel an instantaneous preload of 80%.

## INTRODUCTION

There are many tests for laminates which can be used to show the effects of moisture on their strengths. It is, however, very difficult to relate the strengths of small portions of the laminate in flexure or tension to the strengths that we would expect to get from filament wound pressure vessels. The reason is not hard to see. The role of the resin in a flexural specimen is quite obvious. It has to transfer loads from filament to filament as well as maintain the specimen itself in shear; so any weakening of the bond between the resin and the glass, or change in the strength characteristics of the resin could affect the laminate behavior markedly.

With pressure vessels, we have quite another story: Here there should be relatively little shear in the resin itself, so any direct weakening in the shear modulus of the resin due to water or other factors might not necessarily reflect itself in the strength of the vessel. For this reason, the decision was made to wind small pressure vessels to determine the effects of moisture and environment on pressure vessels themselves rather than try to relate the behavior of small tablets in flexure to the actual behavior of vessels.

A rapid and simple system for making internal pressure vessels was developed so that we could determine statistically what the influences of different resins, glasses, tensions, repeated loadings, environments, etc. might be on the strength of those vessels. Our winding system is such that a large number of specimens can be made essentially simultaneously and hydrostatically tested by an adapter on the INSTRON tester. An illustration of the winding machine with a vessel being wound is shown in Fig. 1.

## EXPERIMENTAL METHODS

All of the vessels were wound on the winding machine shown in Fig. 1. The dry wound vessels were wound at a tension of 14 lbs. of 20-end HTS/E787 regular and wide band prepreg supplied by U. S. Polymeric Co. They were cured at 275° F. for 24 hours while being rotated on a horizontal axis. The wet wound vessels were wound of Owens-Corning 12-end HTS roving under 2 lbs. tension. Three series of vessels were made from rolls "A", "B" and "C". The resin used was 100 parts Epon 828, 90 parts Nadic Methyl Anhydride and 1 part Dimethyl benzylamine. They were cured at 250° F. for 24 hours while being rotated on a horizontal axis.

The tests associated with the investigation of proof testing were wound from the same roll to avoid errors due to differences between rolls. In order to confirm that the adverse effects of proof testing resulted from holding the load at 80% for a minute rather than a rapid increase and reduction of load to this value, another series of tests was conducted with another roll of roving to show the effects of rapid preloading of the vessel to 80%. These rolls were compared to the burst pressures obtained from a similar series of vessels stored without preload. The results are shown in Table III.

## DISCUSSION OF RESULTS

The application of a Student "t" test to the effects of regular prepreg, wide band prepreg and wet winding shows there to be no significant differences in strengths between the regular and wide band prepregs. Wet winding strengths are significantly better in 2 rolls out of 3 used.

A similar test applied to the effects of preloading to 80% of burst and storing the vessels for a week compared to a series merely stored without preload shows no significant reduction of strength. If, however, the vessels have been preloaded to 80% and then held at this value for a minute, as might simulate proof testing, then there is a probability of strength reduction of better than 99% and this amounted to 8% in our case compared to those preloaded to 10% of burst. This was done to simulate loading due to handling.

This effect can be summarized by stating that proof testing at 80% for a minute is detrimental whilst merely raising and then immediately lowering the pressure is not.

## CONCLUSIONS

1. That the strength differences between ordinary prepreg and wide band prepreg are insignificant.

2. Wet winding appears to be better than dry winding in two rolls out of the three that we have used. Further investigation of the variations from roll to roll both of prepregs and of ordinary roving seems indicated.

3. That proof testing by holding the vessel at 80% of the burst pressure for one minute reduces the strength of the vessel. Unsustained loading to this level does not affect its strength. In our case the vessel strengths were reduced about 8% by the one minute loading.

## EXPERIMENTAL DATA

### TABLE I

| 20 End Prepreg | | | | 20 End HTS Wet Wind | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| REGULAR | | WIDE BAND | | Roll A | | Roll B | | Roll C | |
| Vessel | Load/end | Vessel | Load/end | Vessel | Load/end lbs. | Vessel | Load/end lbs. | Vessel | Load/end lbs. |
| EZ-2 | 6.23 | ST-1 | 6.05 | S-1 | 7.01 | BB-3 | 5.70 | SH-8 | 7.48 |
| EZ-4 | 5.40 | ST-2 | 5.87 | S-3 | 6.73 | BB-4 | 5.37 | SH-6 | 6.35 |
| EZ-6 | 6.45 | ST-3 | 6.50 | S-5 | 6.55 | BB-5 | 6.24 | SH-4 | 7.68 |
| EZ-7 | 5.50 | ST-4 | 5.78 | T-1 | 6.76 | BB-6 | 6.24 | JO-9 | 7.28 |
| EZ-9 | 5.87 | | | T-3 | 7.14 | BB-7 | 5.61 | SG-6 | 8.63 |
| EZ-10 | 6.63 | | | | | BB-9 | 6.72 | | |
| Average | 6.20 | | 6.05 | | 6.84 | | 5.97 | | 7.48 |

TABLE II

Effects of Proof testing

Storage: One month at laboratory conditions.

| Prestressed 80% held 1 minute | | Prestressed 10% held 1 minute | |
|---|---|---|---|
| Vessel | Load/end lbs. | Vessel | Load/end lbs. |
| SE-1 | 6.54 | SE-4 | 7.19 |
| SE-1 | 6.71 | SE-7 | 7.44 |
| SE-3 | 6.60 | SE-8 | 6.59 |
| SE-5 | 6.61 | SE-9 | 7.16 |
| SE-6 | 6.33 | SE-10 | 7.06 |
| Average | 6.56 | | 7.09 |

From "t" Test: P = 99%

TABLE III

Effects of instantaneous preload

Storage: One week at laboratory conditions.

| 80% Preload unsustained | | No preload applied | |
|---|---|---|---|
| Vessel | Load/end lbs. | Vessel | Load/end lbs. |
| SJ-7 | 6.82 | SG-6 | 8.63 |
| SH-3 | 7.17 | SH-4 | 7.68 |
| SJ-5 | 8.10 | SH-6 | 6.35 |
| JO-11 | 6.45 | JO-9 | 7.28 |
| JO-10 | 6.98 | SH-8 | 7.48 |
| Average | 7.10 | Average | 7.48 |

From "t" Test: P = 60%

Fig. 1. A view of the "ball-winding" machine.